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AD NUMBER
AD077438
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
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NAVORD REPORT 4040

RESULTS OF A TELEMETERING INVESTIGATION OF PARACHUTE OPENING ALTITUDE OF THE UNIVERSAL PARACHUTE PACK ON THE MINE CASE MK 36

22 AUGUST 1955

U. S. NAVAL ORDNANCE LABORATORY

WHITE OAK, MARYLAND

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RESULTS OF A TELEMETERING INVESTIGATION OF PARACHUTE OPENING ALTITUDE OF THE UNIVERSAL PARACHUTE PACK ON THE MINE CASE MK 36

Prepared by:

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ABSTRACT: This report gives the results of an investigation of the parachute opening altitude of the Universal Parachute Pack when used with the Mine Mk 36. This investigation was conducted while the mine was in free flight by use of radio telemetering equipment. A description of this equipment is included in the report. Results of tests conducted indicate that the parachute opening altitude will not be the design value due to two causes; the pressure sensed by the Control Unit is not free stream static pressure and the pressure switch is set into a violent oscillatory motion.

U. S. NAVAL ORDNANCE LABORATORY
White Oak, Silver Spring, Maryland

NAVORD Report 4040 22 August 1955

It is intended that the information contained in this report will be used by persons concerned with the design of parachute opening devices for mines. The work represented by this report was authorized under task number C7a-308-1-56.

JOHN T. HAYWARD
Captain, USN
Commander

R. E. Hightower
R. E. HIGHTOWER
By direction

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RESULTS OF A TELEMETERING INVESTIGATION OF PARACHUTE OPENING ALTITUDE OF THE UNIVERSAL PARACHUTE PACK ON THE MINE CASE MK 36

INTRODUCTION

1. The Universal Parachute Pack for aircraft launched mines incorporates the Control Unit Mk 66 Mod 0 as a sensing unit for parachute opening. The control unit contains a pressure switch which initiates parachute opening when the mine has descended to a nominal altitude of 3000 feet. Field tests conducted during development of these devices indicated that the parachute opening altitude varied excessively from 3000 feet for certain types of mines. This causes the trajectory of the mine to be unpredictable and increases the bombing error. Laboratory tests failed to indicate the cause of this variation in parachute opening altitude so it was decided to investigate this effect under field conditions with the aid of radio telemetering equipment.

2. The purpose of this report is to describe the results of this program and the test methods employed.

3. All of the tests conducted during this program used the following standard equipment:

Mine Case Mk 36, inert loaded to simulate Mine Mk 36 Mods 0, 1 and 2

Parachute Pack XP-24A

Control Unit Mk 66 Mod 0

Several different release mechanisms

The Mine Case Mk 36 was chosen for this work because it's parachute opening altitude varied considerably and was, in general, higher than 3000 feet and, also, because these mine cases were readily available.

Pressure Measurements

4. The Pressure Switch Mk 5 Mod 0 consists of an evacuated metal bellows with a set of switch contacts. As such, it is essentially a modified aneroid barometer. Laboratory pressure tests of this device indicated that it was operating in the prescribed manner. It was believed that the pressure in the instrument compartment where the pressure switch was located might be different from the free stream static pressure in the immediate vicinity of the mine. In the case of

the Mine Case Mk 36, it was expected that the pressure in the instrument compartment would be higher than free stream static pressure. This would account for the fact that the parachute usually opened high for this mine. It was decided to measure this pressure while the mine was in flight to see if this theory was correct.

5. The telemetering equipment used was the so-called FM-FM telemetering system in common use for large missiles. In this case the following equipment was installed in the mine: a 2 watt, 220 mc, FM transmitter, an antenna, two sub-carrier oscillators, two pressure gages, a pitot static tube, and a power supply. The pitot static tube was mounted on the front of the mine case and extended about forty inches in front of the mine case. The pitot static tube served two functions; it sampled the free stream static pressure in the vicinity of the mine and it also served as the transmitting antenna. The pressure gages were of the variable inductance type. These gages were each electrically connected to a subcarrier audio oscillator. As the pressure changed on a gage, the gage inductance would assume a different value and this, in turn, would cause the frequency of the subcarrier oscillator to change. (Frequency Modulation) The subcarrier oscillators were operating at widely separated frequencies. The signals from these oscillators were added electrically and used to frequency modulate the transmitter. A brief sketch of the arrangement of these components is shown in Figure 1.

6. The pressure gages are such that they measure the difference in pressure between two input pressure hoses. One pressure gage was connected to the static tube which served as one input and a closed reference pressure vessel which served as the other input. With such a system this particular gage would measure the free stream static pressure in the vicinity of the mine and from this it would be possible to determine the altitude of the mine at any instant. A thermos bottle was used as a reference pressure vessel for the first tests, the object being to maintain the enclosed air at constant temperature and hence constant pressure. It has been observed that the parachute opening altitude was more unpredictable when the mine was dropped from high altitude. It was decided that the early tests be dropped from 30,000 feet, if possible. The altitude pressure gage was chosen to have a range of 0-10 psi to measure this high altitude.

7. The gage noted as Differential Pressure Gage in Figure 1 was connected in such a way as to measure the pressure difference between the instrument compartment and free stream static pressure as observed by the static tube. This method

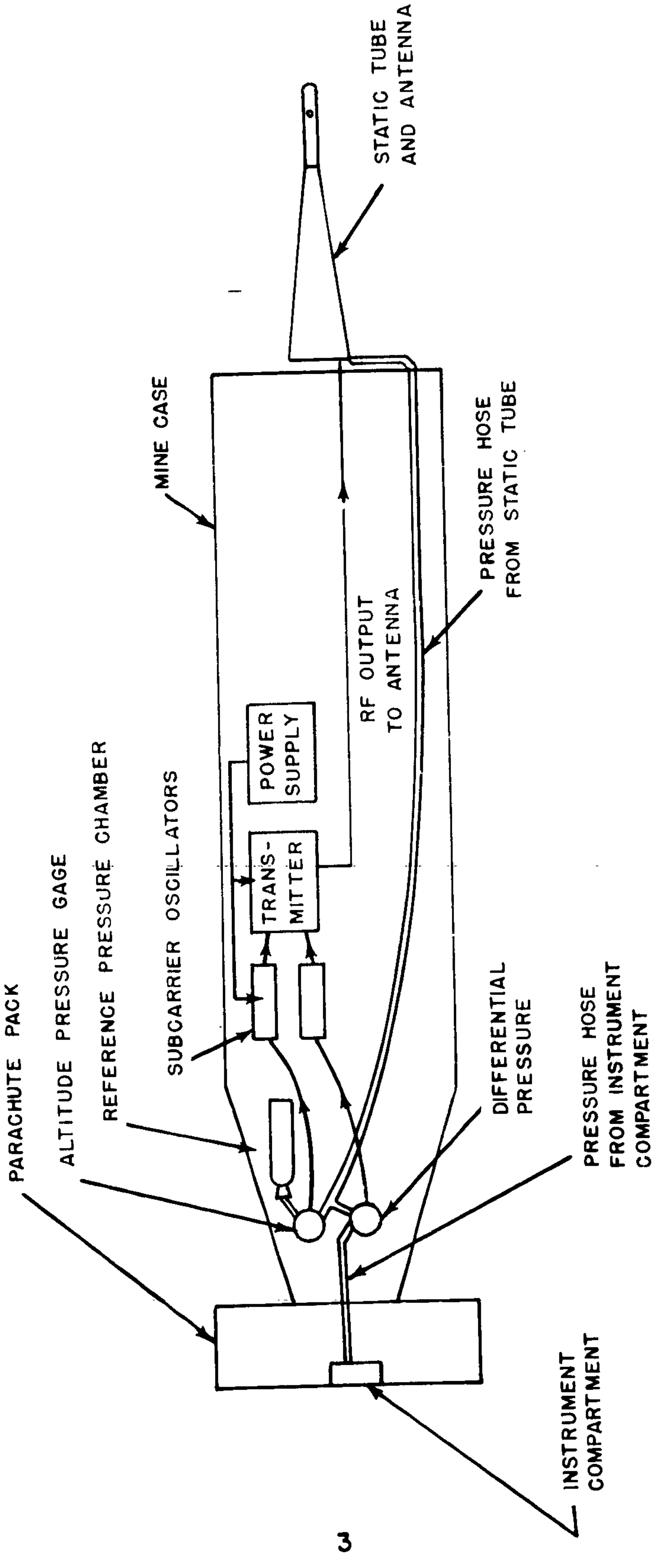
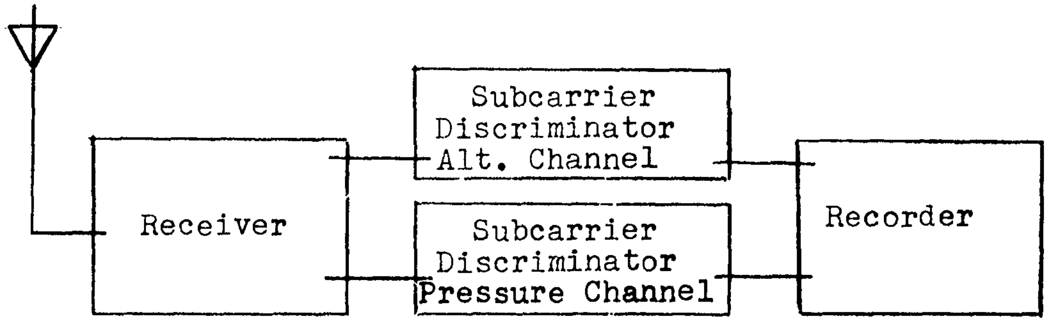


FIG. I MINE CASE INSTRUMENTATION
FOR FIRST TESTS

was chosen in preference to measuring the absolute pressure in the instrument compartment because it was felt this method would more accurately check the theory stated in paragraph 4. A ±5 psi gage was initially chosen for the first series of drops.

8. The equipment described above represented an investment of about $1000 per mine unit and it was felt that this equipment should be recovered after each drop, if possible. This required that the mines be dropped on a land target. The first tests were arranged such that when the parachute opened, the parachute pack and mine case would separate and all telemetering equipment, except the power supply and antenna, would float down on the parachute. It was thought that this would decrease the parachute load and hence reduce the equipment damage at ground impact. Since the Control Unit gave unpredictable parachute opening altitudes, it was decided to use a demolition timing device as a parachute opening mechanism.

9. The ground receiving station consisted of a receiving antenna, an FM receiver, two subcarrier discriminators, and a two-channel graphic recorder. Each subcarrier discriminator contained a bandpass filter tuned to the respective subcarrier oscillator frequency in order to separate the information channels. A sketch of the receiving equipment is shown in Figure 2.



Telemetering Receiving Station
Figure 2

10. This project was started in December 1953. In order to drop from 30,000 feet on a land target, it was necessary to arrange the drops at Navy Auxiliary Air Station, El Centro, California, during April and May 1954. The first set of instrumentation was completed in February 1954. An instrument drop was conducted at Naval Proving Ground, Dahlgren, Virginia during March 1954. This drop was made from 15,000

feet. The primary purpose of this test was to determine the effectiveness and operating performance of the instrumentation system. The parachute was opened by the demolition timing device after about 32 seconds flight time at an altitude of 3100 feet. No provision was made to separate the mine case and parachute at parachute opening since the release mechanism had not yet been completed.

11. This test indicated that several changes in instrumentation were desirable. First, the observed variation in the differential pressure was only about 0.5 psi, indicating that the range of the differential pressure gage should be reduced to 1 or 2 psi. Second, the altitude as determined from the pressure readings were in poor accord with altitude as determined by theodolite observations. This second effect was believed to be due to temperature variations affecting gage calibrations. It was believed that this effect could be reduced by thermally insulating the gages. The mine missed land and fell into the river. All of the equipment was lost and no information was obtained about instrument recovery techniques.

12. The differential pressure gage indicated that the pressure in the instrument compartment was about 0.5 psi less than free stream static pressure at the time of parachute opening. This was only about 5% of the total range of this gage and this is approaching the expected measurement error. Later tests with more sensitivity gages indicate the same order of magnitude of the differential pressure. This differential pressure should cause the parachute to open about 1000 feet below its normal value. This effect is quite the opposite of that expected as outlined in paragraph 4.

13. As a result of this first Dahlgren test, the range of differential pressure gages used on the El Centro drops was reduced to ± 2 psi. The gage mountings were changed slightly and the gages were packed in rock wool for thermal insulation. The design of the antenna and static probe was changed in order to make it easier to fabricate.

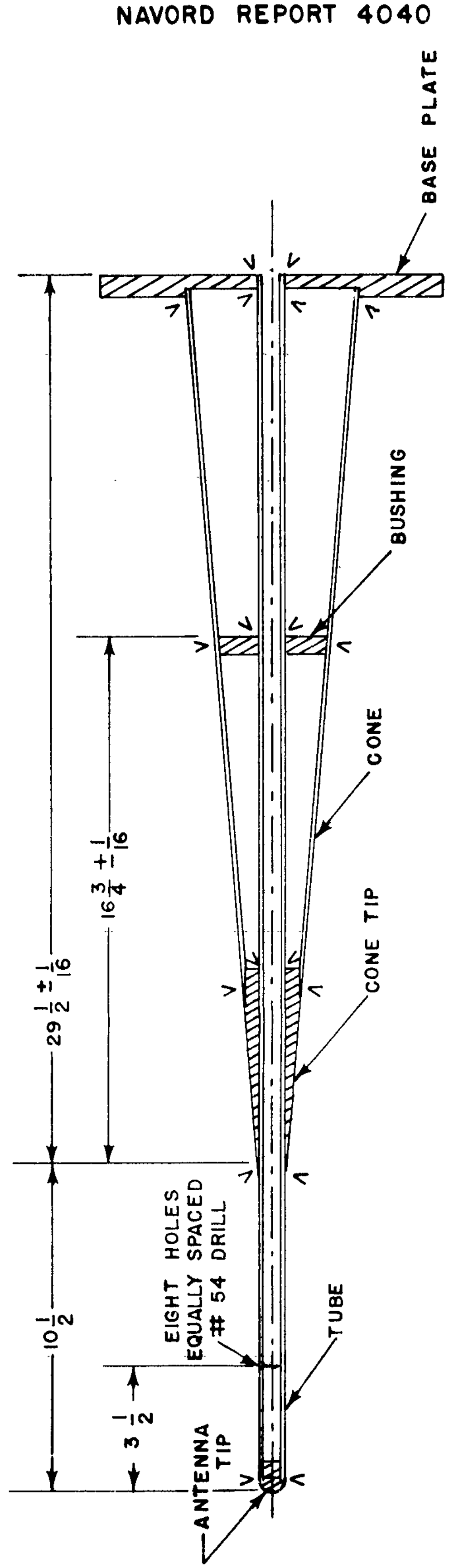
14. Seven mines with telemetering equipment as described were dropped at NAAS El Centro, California during April and May 1954. These tests were unsuccessful in that very little useful information was obtained. The tests were unsuccessful primarily because the mine case, with static probe attached, exhibited an unstable flight characteristic. When the antenna design was changed after the first Dahlgren test, it apparently shifted the center of pressure forward of the center of gravity of the mine case. This would cause the mine case to pitch, yaw, and tumble. The velocities obtained by the mine case during unstable flight were much less than the normal velocity. The pressure distribution

about the mine case and in the instrument compartment were no longer typical, and the static probe would no longer read true static pressure. The true cause of these difficulties was not recognized until after the seventh mine case was dropped. This was the first one that was visually observed during this unstable flight.

15. Additional difficulties were observed with the instrumentation. In two cases, the thermos bottle apparently leaked or was broken before launching. This would cause the altitude information to be useless. The gages apparently were still undergoing temperature changes which would cause the calibration to be incorrect. The demolition timing devices were not functioning correctly and the parachute would open at the wrong time. In some cases, when the mine case and parachute would separate, the instrumentation would be damaged. This could occur if the separation forces were not parallel to the longitudinal axis of the mine. Since the mine case velocity was slow and the timing device was not functioning correctly, the parachutes would open very high. Some parachutes opened at about 13,000 feet. With only the instrumentation as a load for the parachute, they would drift for miles and most of the instrumentation was lost or damaged.

16. The El Centro tests indicated that the flight stability of the mine case had to be improved before further telemetering tests could be conducted. Wind tunnel tests were made during July 1954 in the University of Maryland wind tunnel. These tests were designed to determine an antenna-static tube configuration that would not cause the mine to be unstable. These tests indicated that the static tube should extend at least forty inches forward of the mine case in order to sample free stream static pressure. They showed, in addition, that the mine case with its flight gear was only marginally stable. This led to the conclusion that any antenna-static tube on the front on the mine could only cause the mine to be more unstable. Figure 3 illustrates an antenna design that performed best in the wind tunnel tests. However, this antenna also caused the mine to be more unstable than the mine case alone. It was concluded that in order to improve the stability of the mine with an antenna, it would be necessary to increase the size of the stabilizing fins on the after part of the mine. This was done as shown in Figure 4. All telemetering tests conducted after this date used these fins.

17. It was recognized that these fins might cause the pressure in the instrument compartment to be slightly different than the normal case where the fins were not present. It would seem that this is part of the price that must be paid in order to conduct this measurement.



V INDICATES SOFT SOLDER ASSEMBLY

FIG. 3 ANTENNA ASSEMBLY

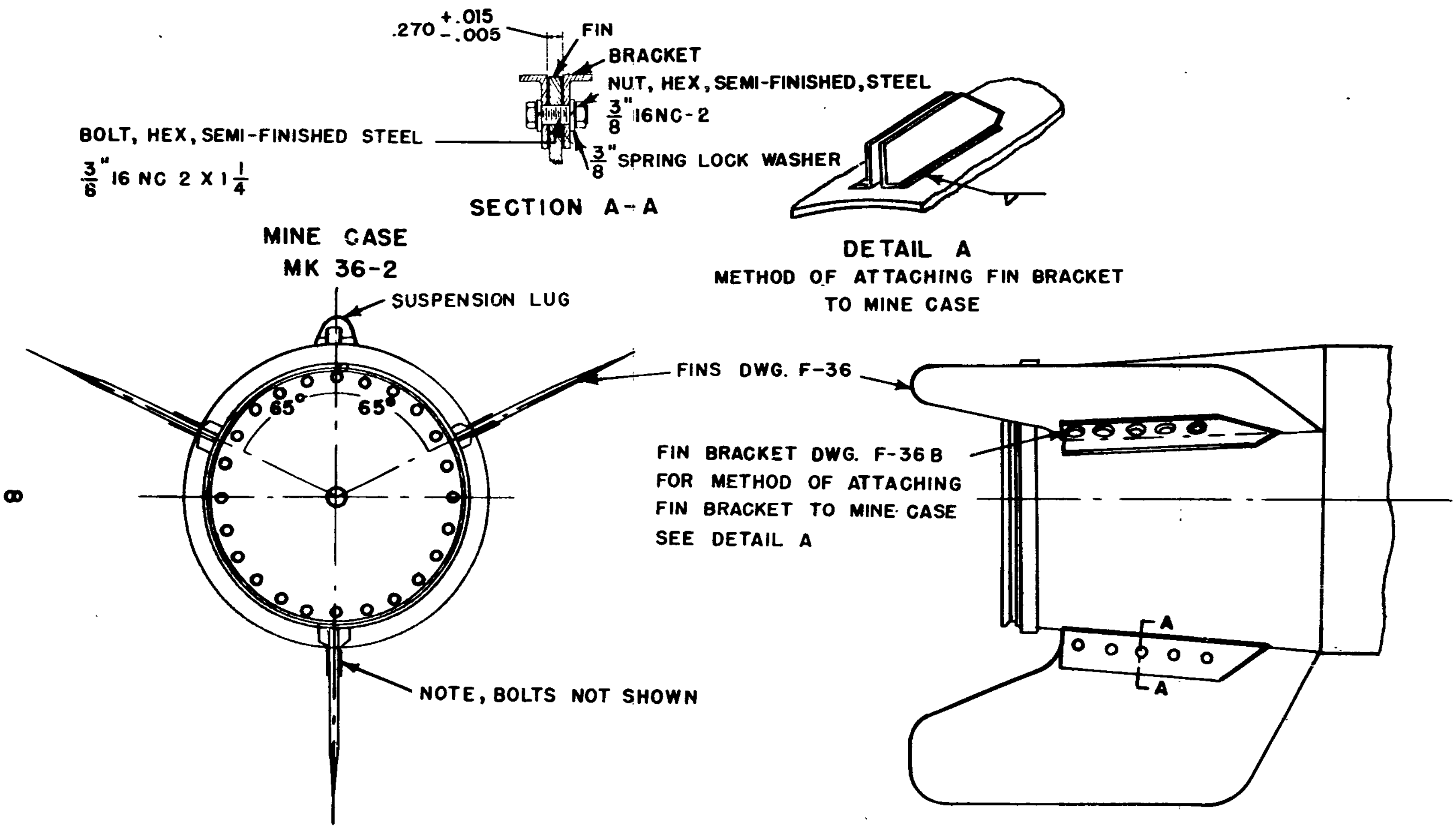
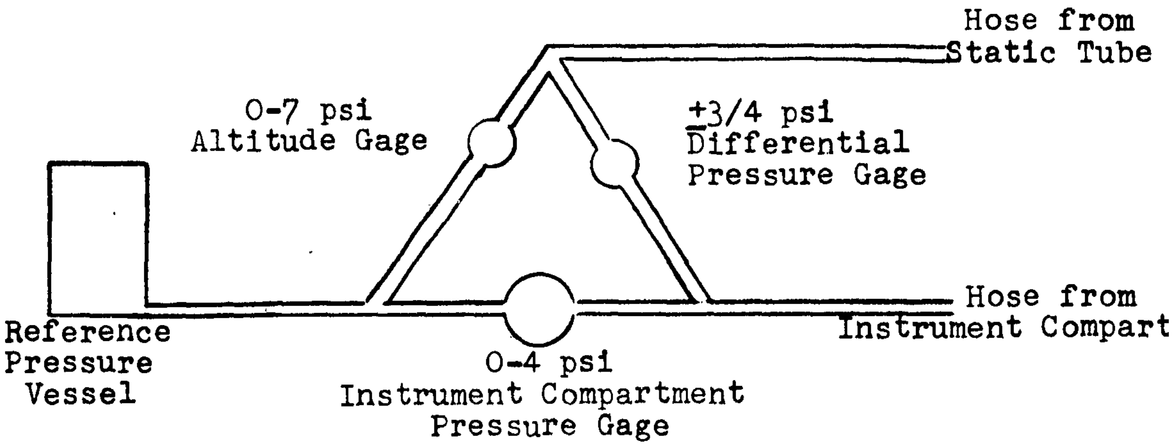


FIG. 4 FIN ASSEMBLY

18. Two more mine cases were instrumented with telemetering equipment. These mine cases were dropped from 15,000 feet at Dahlgren. The large stabilizing fins of Figure 4 were attached to the mine case. An additional pressure gage and subcarrier oscillator were added. The pressure gages were arranged as shown in Figure 5.



Pressure Gage Connection Details
Figure 5

19. The reference pressure vessel was fabricated from heavy brass sheet and the pressure gages were mounted directly on the reference pressure vessel. The pressure gages were calibrated at several temperatures. Two thermistors were also mounted on the reference pressure vessel. The thermisto: were incorporated into a fourth subcarrier oscillator that would measure the temperature of the pressure gages and reference pressure vessel. The pressure gage-reference vesse assembly was packed in rock wool for thermal insulation. It was hoped that these precautions would eliminate the temperature errors in the pressure data.

20. These two mines were dropped at Dahlgren, Virginia on November 9, 1954 from 15,000 feet. The aircraft speed was 140 knots. Altitude and differential pressure as a function of time are illustrated in Figures 15 and 16. The parachute pack opening devices functioned in both cases. The parachute did not open because the hose from the instrument compartment inadvertently held the parachute pack cover on. The Control Unit Mk 66 Mod 0 was used as a parachute opening device on both drops. No attempt was made to separate the mine case and parachute at parachute opening time as in the El Centro tests.

21. As can be seen in Figures 15 and 16, the pressure in the instrument compartment was always less than free stream

static pressure. At the time the pack opener functioned, the differential pressure was about 30 mm Hg. This pressure differential should have caused the pack opener to function 1100 feet below normal altitude. The actual altitudes at which the pack openers functioned were 3050 feet and 4350 feet. The sudden discontinuity in the differential pressure was due to the parachute pack cover partially coming off when the pack opener functioned. This caused the pressure in the instrument compartment to change suddenly.

22. These tests indicated that the pressure in the instrument compartment was not free stream static pressure. The differential pressure is of sufficient magnitude to alter the performance of the Control Unit from the expected manner. However, these tests did not explain the complete picture. Based on these pressure tests alone, it would be expected that the parachute would open too low. This was not the case as shown by the altitudes at which the pack opener functioned in these two mines.

Vibration Measurements

23. There was meager laboratory evidence that the pressure switch was effected by vibration at its resonant frequency which was about 100 cycles per second. Vibration could cause the switch contacts to close prematurely and thus cause the parachute to open too high. It was decided to attempt to measure the vibration (if any) of the outer bellows of the pressure switch.

24. Two mine cases were equipped with fins and telemetering equipment. Pressure gages were arranged as shown in Figure 5, with the same ranges as shown there. The gages were mounted in a small can and waxed as shown in Figures 11 and 12. The can was filled with a mixture of ice and water and then packed in rock wool for thermal insulation. These precautions were taken to insure that the pressure gages and pressure reference vessel would be at exactly 32° F. for several hours.

25. A vibration gage was attached to the pressure switch as shown in Figure 6. This gage consisted of a Meissner type 25009 adjustable RF coil. The iron slug of this coil was cemented to the top of the bellows and the coil portion was mounted on the cover of the pressure switch. Any motion of the bellows would change the relative position of the slug in the coil and thus change the coil inductance. The coil was incorporated into an oscillator at 70 KC. This formed a fourth channel of the system. No temperature gages were included in these mines.

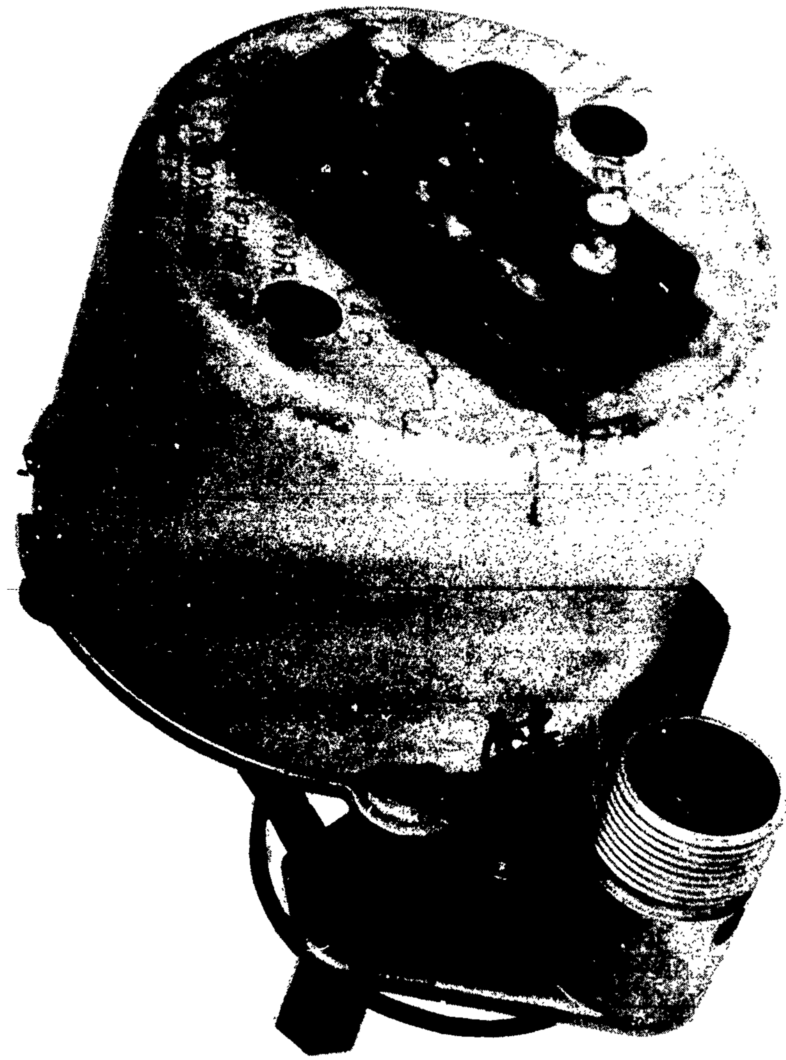


FIG. 6 PRESSURE SWITCH WITH VIBRATION GAGE ATTACHED

26. These mines were dropped in May 1955 at NPG Dahlgren, Virginia from 15,000 feet. The aircraft speed was 140 knots. One transmitter failed shortly after leaving the plane and later commenced operating again just before the parachute opened. The other mine performed in the expected manner. The parachutes opened on both mines and all instrumentation was recovered in reasonably good condition. The altitude vs. time and differential pressure vs. time are shown in Figure 17. The pressure in the instrument compartment was less than free stream static pressure and nearly identical to that obtained for the two previous drops reported in Figures 15 and 16. The vibration gage indicated that the pressure gage bellows was vibrating with a damped oscillatory motion. These oscillations occurred in a random, intermittent manner throughout flight. During the ten second interval previous to parachute opening, these oscillations persisted for about 50% of the time. Figure 18 is a photograph of the pressure record and vibration record at the time of parachute opening. These oscillations can be easily seen during this interval. The amplitude of these oscillations vary of course but roughly they are large enough to cause the parachute to open 2000 feet too high. The frequency of oscillation was 89.5 cps.

27. The data from the second mine indicated the same trend as the first. Due to the intermittent nature of the transmitter, however, it is felt that the data from this mine must be used more in the nature of a supporting statement.

28. The parachute opening altitude for the first mine was 3759 feet; for the second it was 3263. These altitudes were obtained from theodolite observations and are believed to be accurate to within ten feet.

29. It would seem then that the variation in parachute opening altitude is due to two effects. The pressure in the instrument compartment is less than free stream static pressure and this tends to cause the parachute opening altitude to be less than the design value. The bellows on the pressure switch forms a resonant mechanical system at about 100 cps. While the mine is falling, the pressure switch is set into vibration in a random manner at this resonant frequency. This vibration can be sufficient to cause the parachute to open several thousand feet too high. It is expected that both of these effects might be a function of launching conditions and the mine case design.

Description of Telemetering Equipment

30. Several types of transmitters were used in this series of mine drops. The Telemetering Associates Model T-3 is

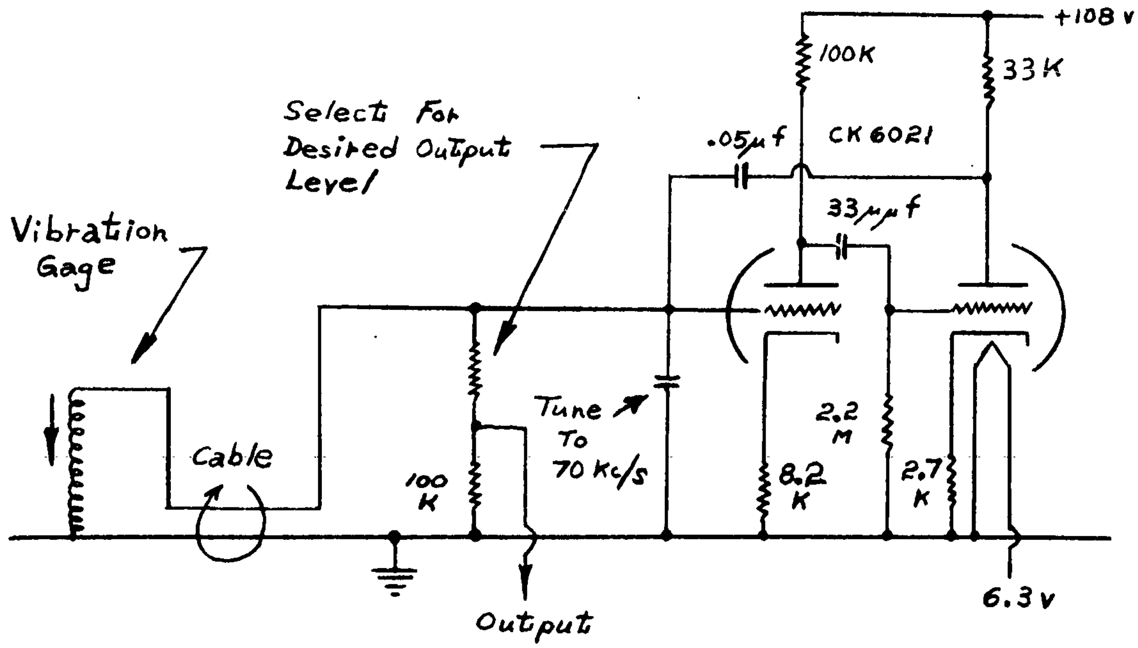
typical. It is an FM Transmitter operating at 218 mc/sec. The RF power output is 2 watts. The input power required is 6.3 volts at 0.6 amp and 180 volts at 0.06 amp. As used in these tests, these transmitters had an effective line of sight range of about 30 miles. A similar type transmitter is shown mounted on the power supply in Figure 7.

31. The power supply was of the battery and vibrator type. The schematic diagram is shown in Figure 8. The power supply was mounted on a circular plate and bolted into the normal battery compartment in the mine case. The power supply is shown in Figure 7. This power supply will operate the telemetering equipment from four to six hours depending upon the temperature.

32. The pressure gage subcarrier oscillators were the Bendix Aviation Company Type TOL-5. These were also mounted on the power supply as shown in Figure 7.

33. The subcarrier oscillator used with the temperature gage is shown in Figure 9. At 70° F. the frequency of oscillation is about 200 cps. The temperature coefficient of frequency is about 3.5 cps/° F. at 70° F. These were also mounted on the power supply.

34. The schematic for the vibration subcarrier oscillator is shown in Figure 10. This was mounted with the other subcarrier oscillators.



Vibration Subcarrier Oscillator
Figure 10

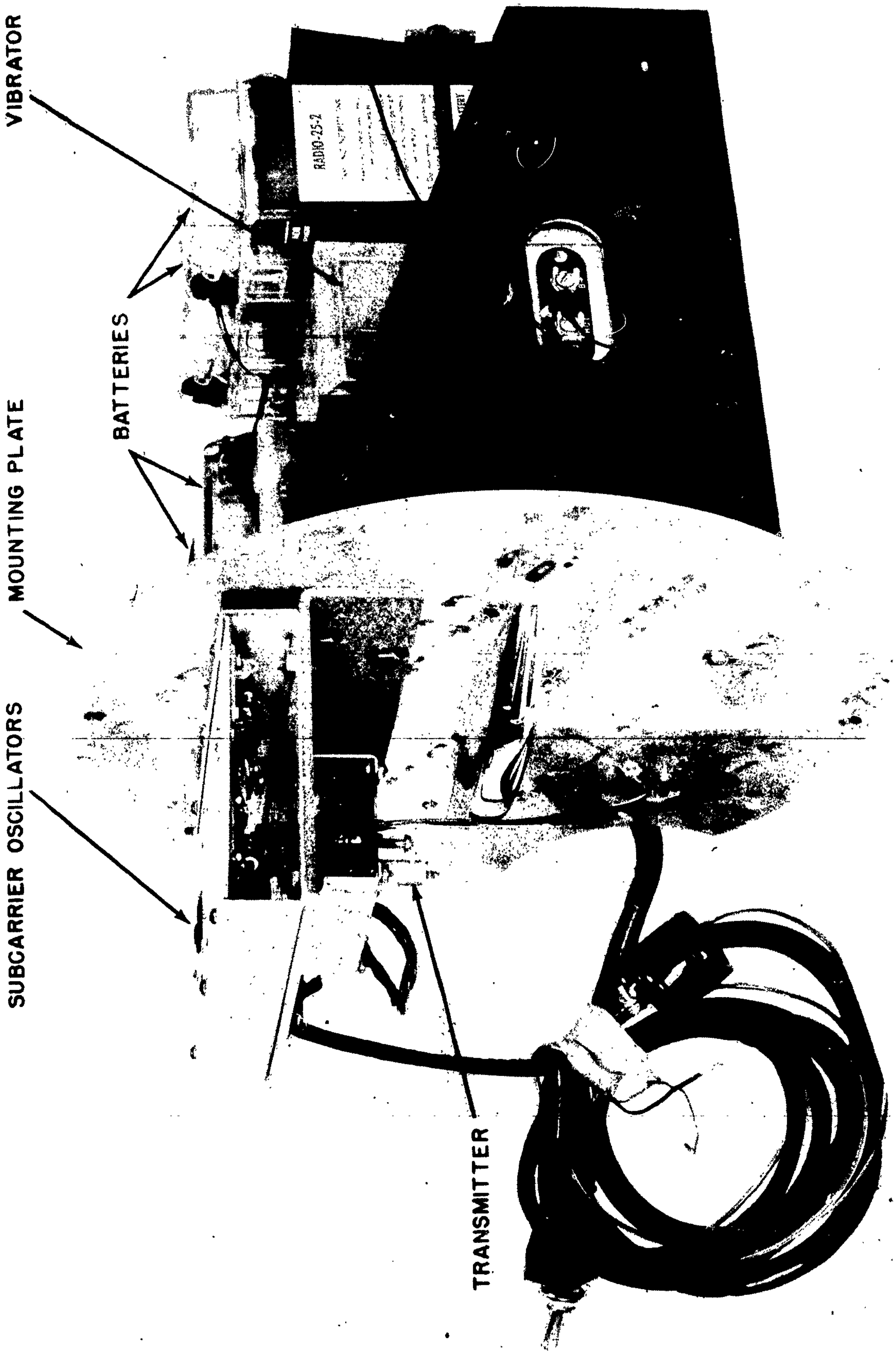


FIG. 7 POWER SUPPLY ASSEMBLY

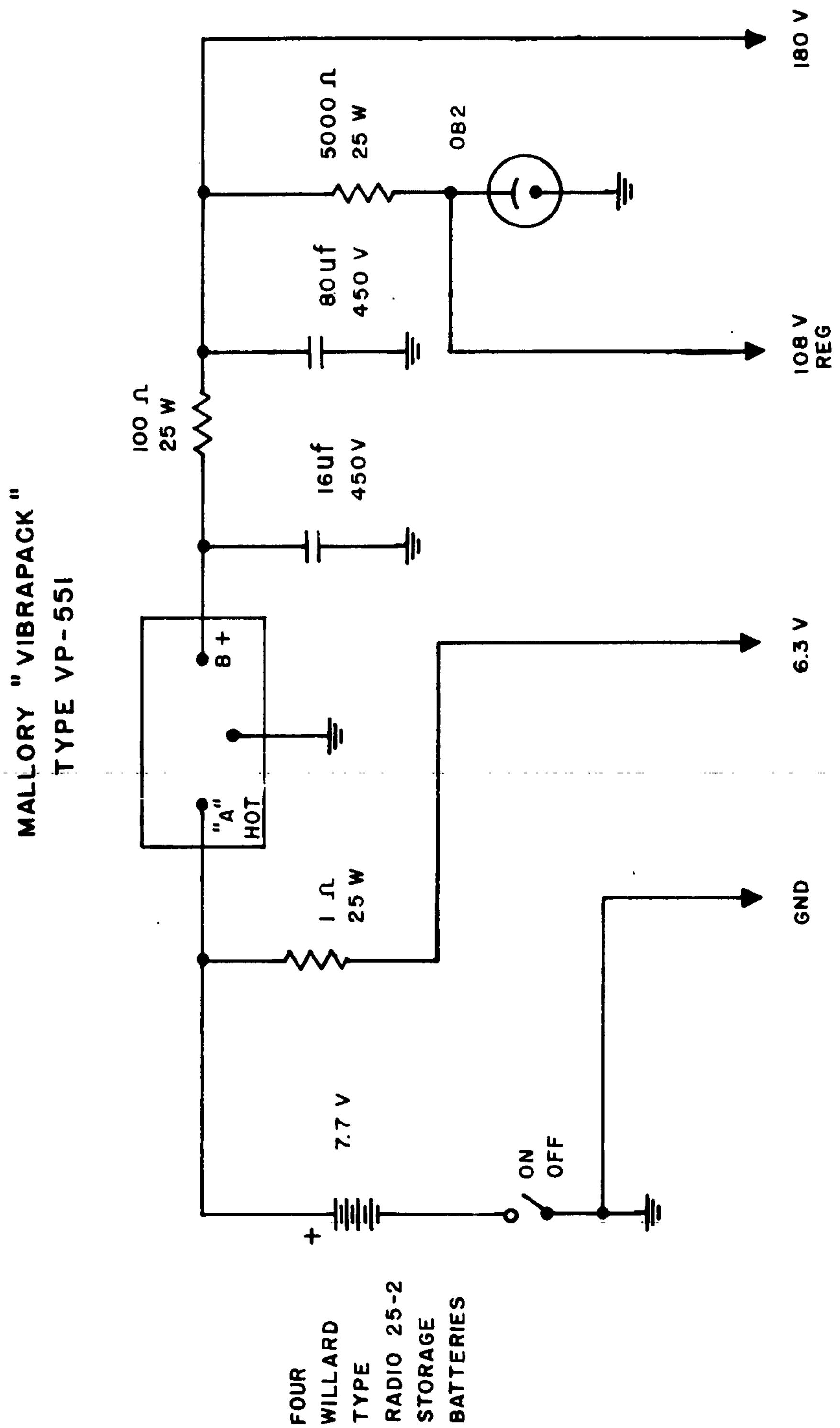


FIG. 8 POWER SUPPLY CIRCUIT DIAGRAM

This oscillator has the undesirable feature that it turns into a multivibrator if the cable to the gage is broken. This was noted when the parachute cover came off in the last two drops. The output signal as a multivibrator is much greater than as an oscillator and it effectively jams the system when this occurs.

35. The pressure gages were Bendix Aviation Company Type TTP-2A and Type TTP-17. These are shown as mounted for the last two drops in Figures 11 and 12. The tuning condenser for each subcarrier oscillator was included in this assembly. The reference pressure vessel consisted of only the copper tube joining the two gages. This probably should be increased in volume on any future drops. The whole assembly was dipped in ceresin wax as shown in Figure 12. When the can is filled with an ice water mixture and packed in rock wool, it will maintain constant temperature for from four to six hours.

36. The transmitting antenna is shown in Figures 13 and 14. It is three-fourths wavelength long and is driven at the base. The large thick washers visible in the photograph are made of polystyrene and form the insulators for mounting. The antenna is mounted in the center of the front plate of the mine. The design of the antenna insofar as its function as a static tube is concerned is essentially according to National Advisory Committee on Aeronautics specifications. The hose connection for the static tube is visible in Figure 14.

CONCLUSIONS

37. The parachute opening altitude as determined by the pressure switch will be different from the design value of 3000 feet due to two partially compensating effects. First, the pressure observed by the pressure switch is less than free stream static pressure. (See Figures 15, 16 and 17) This effect would tend to cause the parachute to open lower than the design altitude. Second, the bellows on the pressure switch is set into large oscillations in a frequent, random manner. (See Figure 18) This effect would tend to cause the parachute to open at a higher altitude than that predicted by pressure alone.

38. It is expected that the first effect will be a function of the launching velocity of the aircraft, launching altitude, flight stability of the mine, and the general mechanical design of the mine case and parachute pack. For the specific combination of these variables encountered in the tests reported here, this pressure effect tends to cause the parachute to open about 1200 feet lower than the design value. It was observed that the pressure in the instrument compartment varied in a violent unpredictable manner when the mine

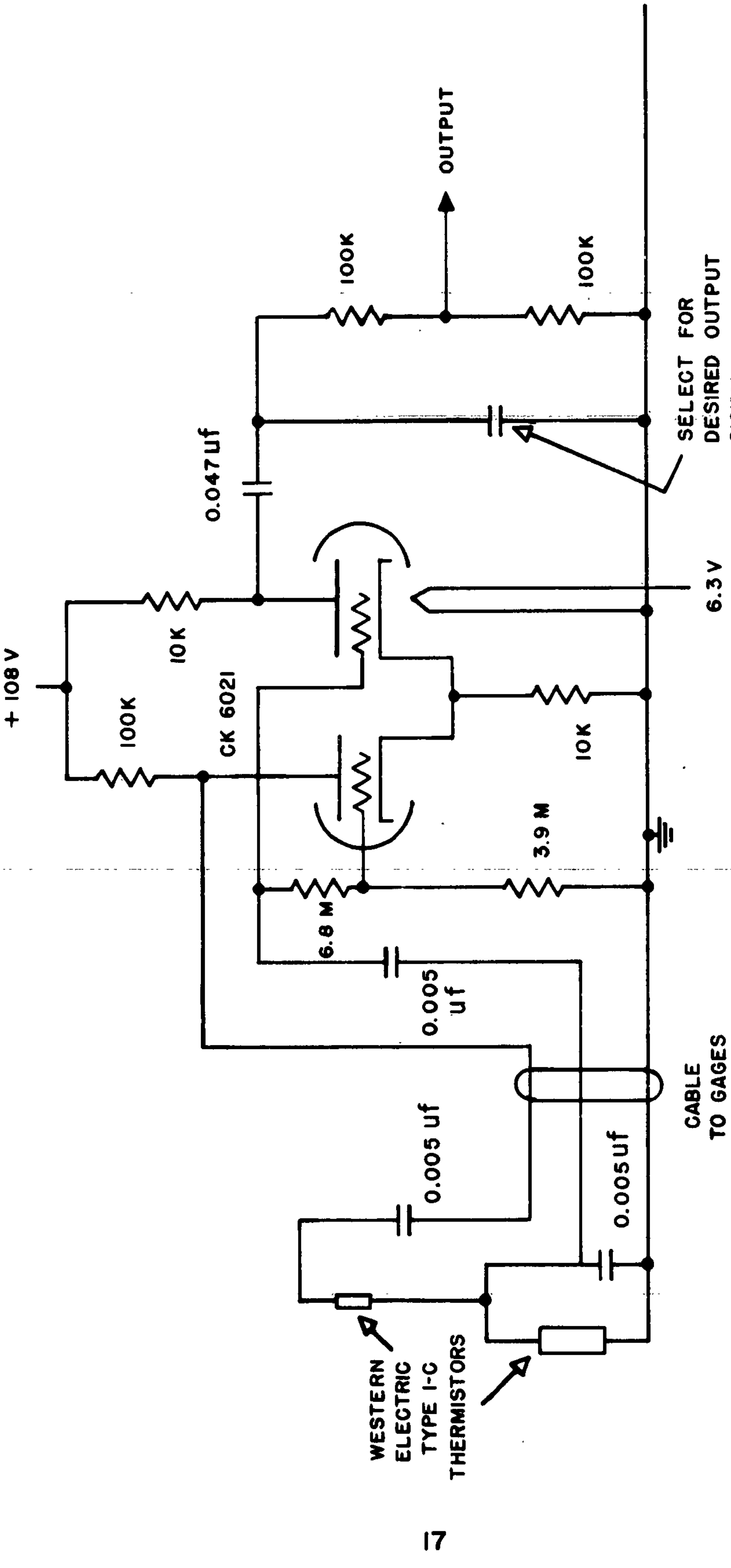


FIG. 9 TEMPERATURE SUBCARRIER OSCILLATOR

FIG. 11 PRESSURE GAGE ASSEMBLY

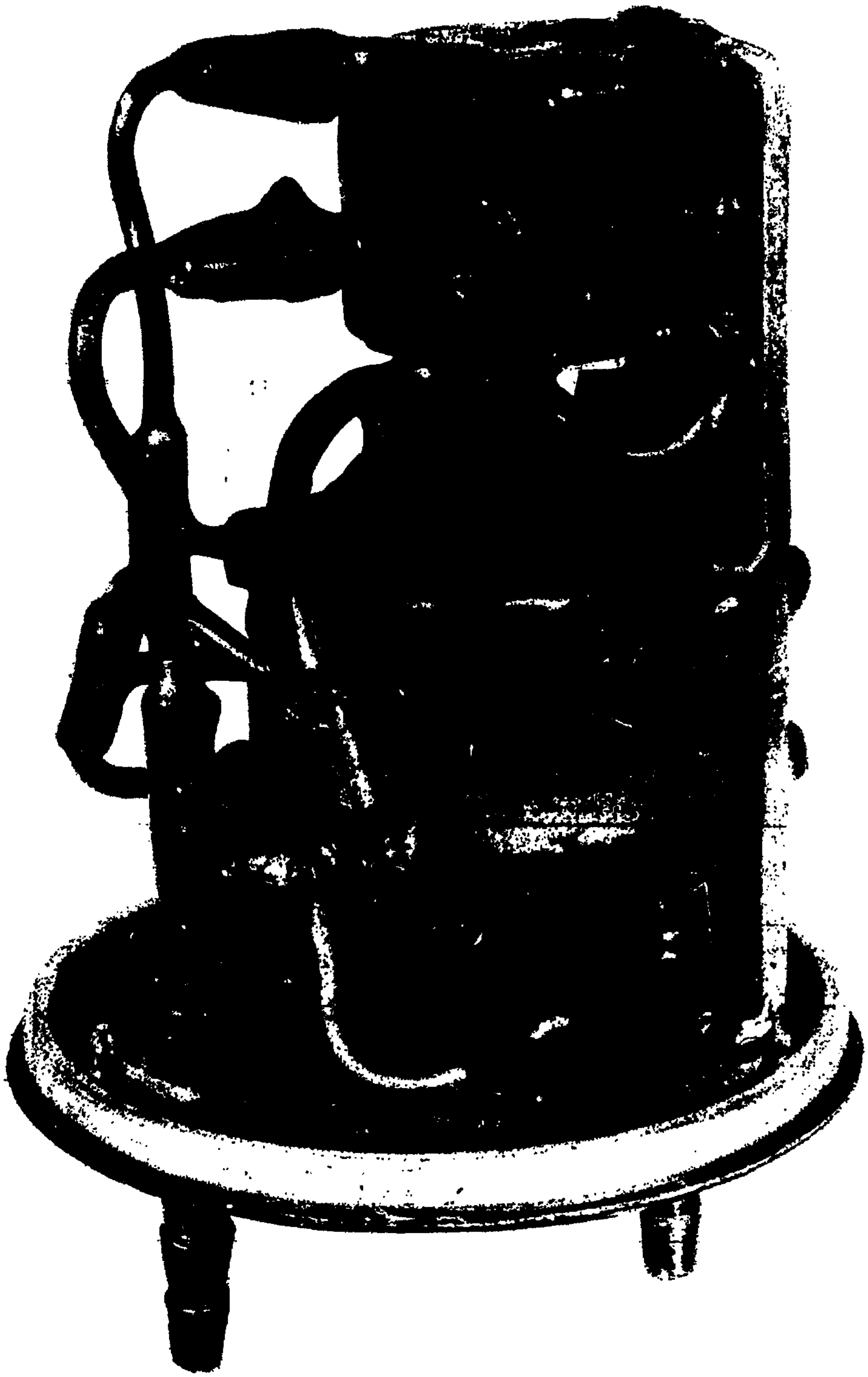


FIG. 12 PRESSURE GAGE ASSEMBLY
(SECOND VIEW)

FIG. 13 ANTENNA STATIC TUBE

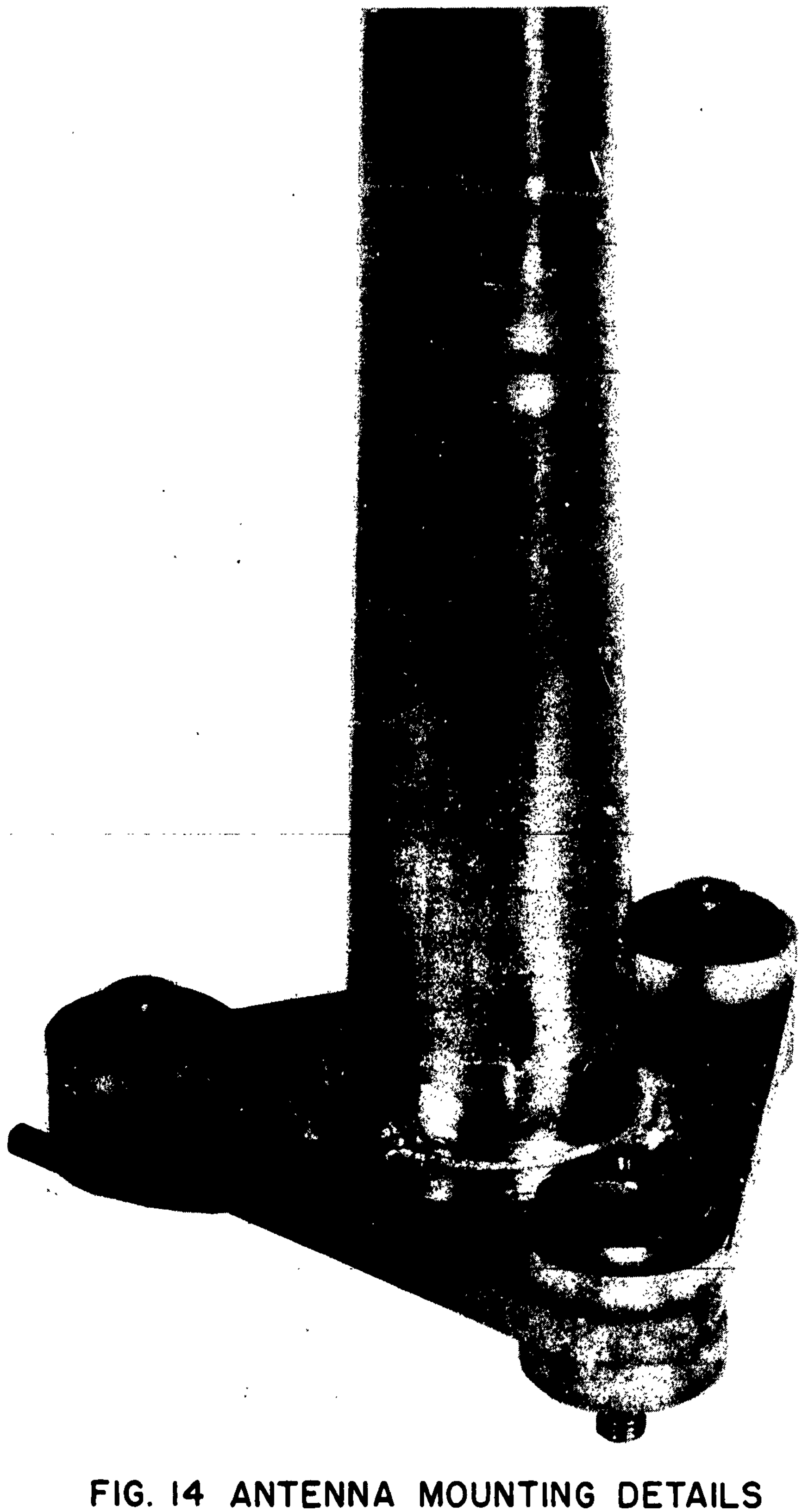


FIG. 14 ANTENNA MOUNTING DETAILS

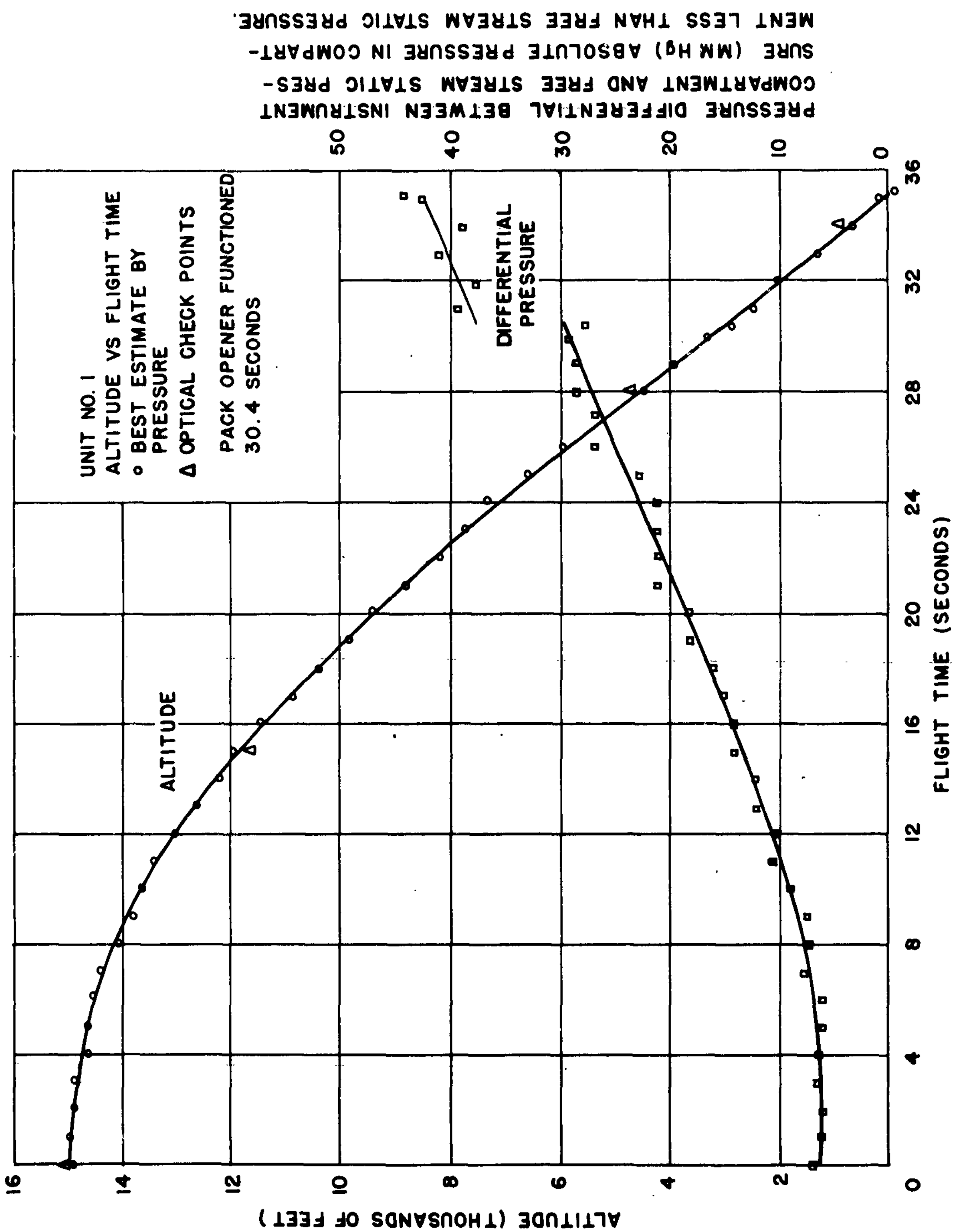


FIG. 15 ALTITUDE AND PRESSURE RECORD FOR FIRST MINE DROPPED 9 NOV 54

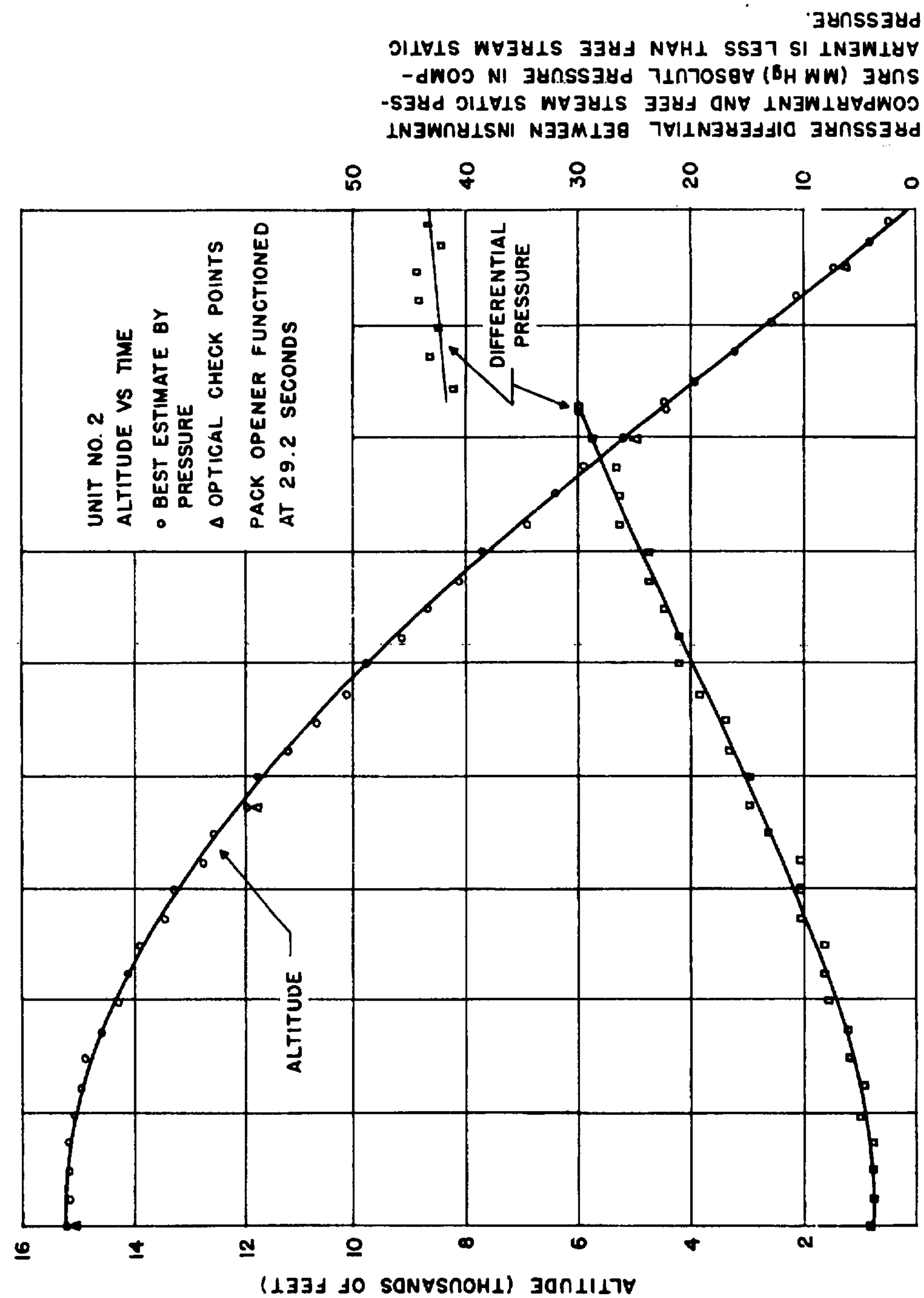


FIG. 16 ALTITUDE AND PRESSURE RECORD FOR SECOND MINE DROPPED 9 NOV 54

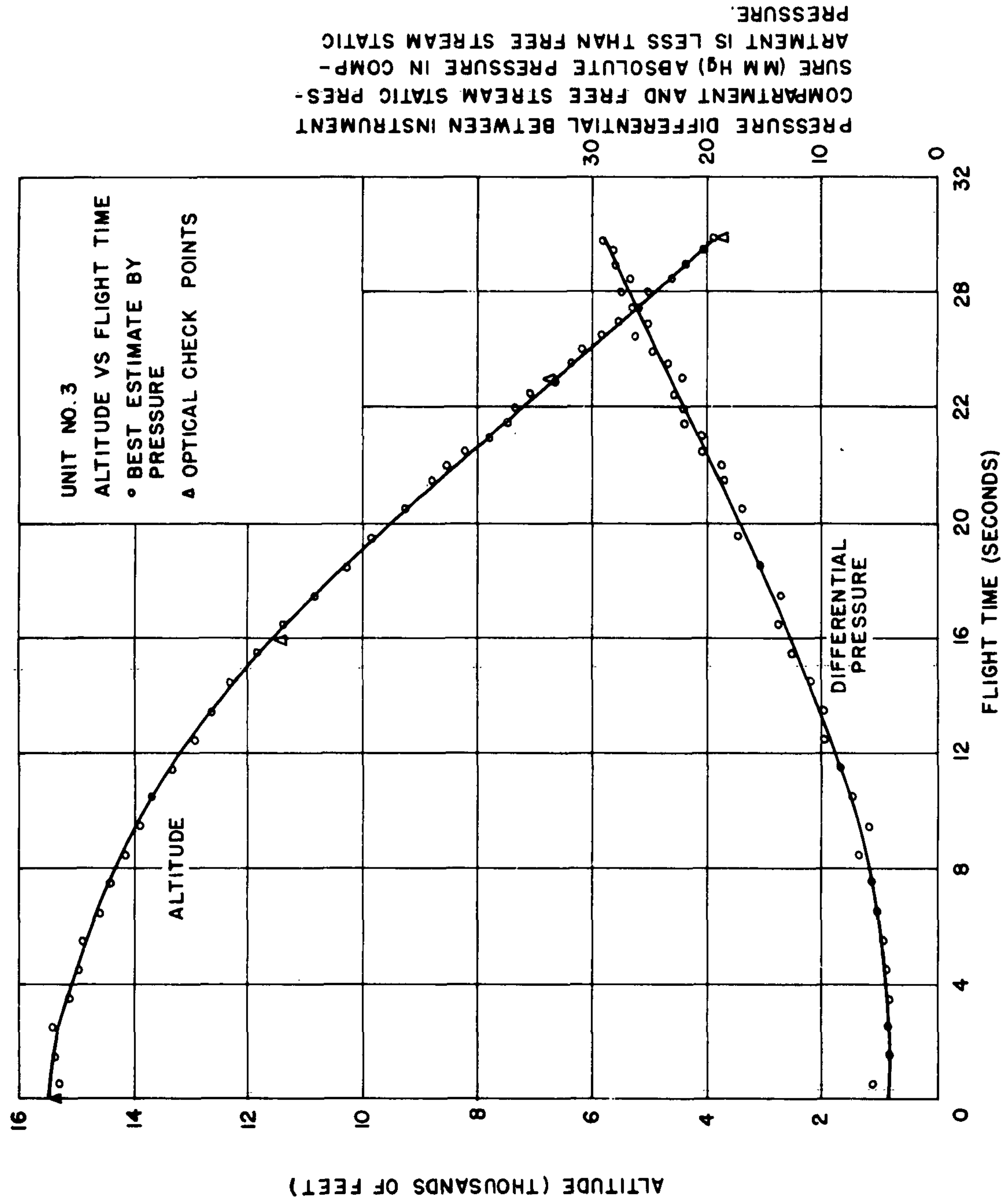


FIG. 17 ALTITUDE AND PRESSURE RECORD FOR FIRST MINE DROPPED 2 MAY 55

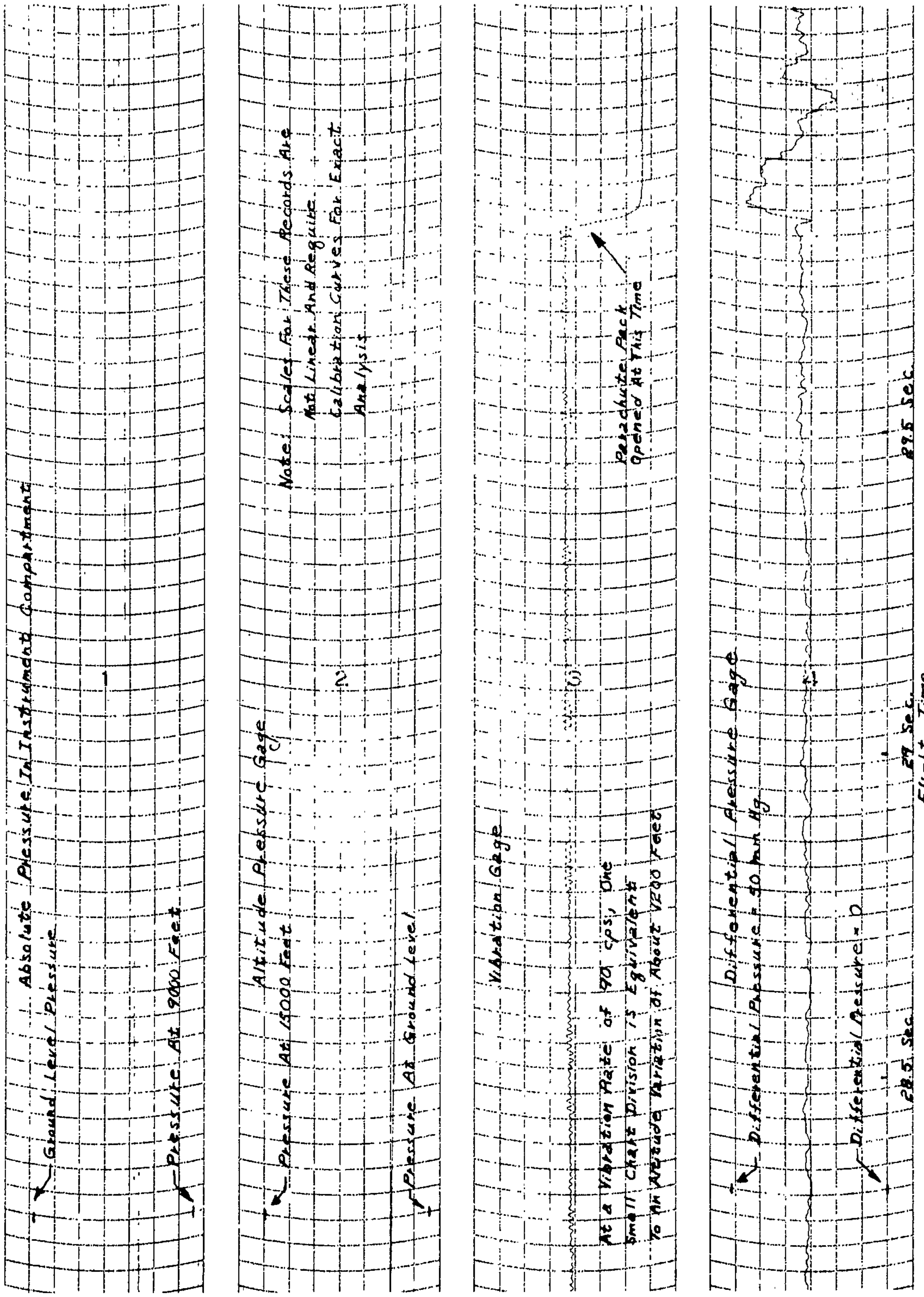


FIG. 18 DATA RECORD OF PRESSURE AND VIBRATION OF PRESSURE SWITCH

has unstable flight characteristics. Wind tunnel tests conducted as an outgrowth of these tests indicate the stability of the mine case is not all that might be desired.

39. The second effect could be caused by buffeting forces acting on the mine case. These forces would be influenced by the same effects that influence the pressure. Since these forces apparently occur in a random manner, it is more difficult to predict the effect upon parachute opening altitude. Under the conditions of the tests reported here, this second effect could cause the parachute to open about 2000 feet higher than that predicted by pressure alone.

40. If the parachute opening altitude is to be made more predictable, it would seem that the following measures must be taken. First, the flight stability of the mine case must be firmly established. The bellows on the pressure switch must be mechanically damped to reduce the amplitude of oscillations. The relationship of the pressure difference between the instrument compartment and free stream static pressure to its several influences must be established and considered in the design or use of the pressure switch. It is conceivable that this pressure difference might be reduced to an inconsequential magnitude by bleeding air into the instrument compartment under the influence of the dynamic pressure.

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